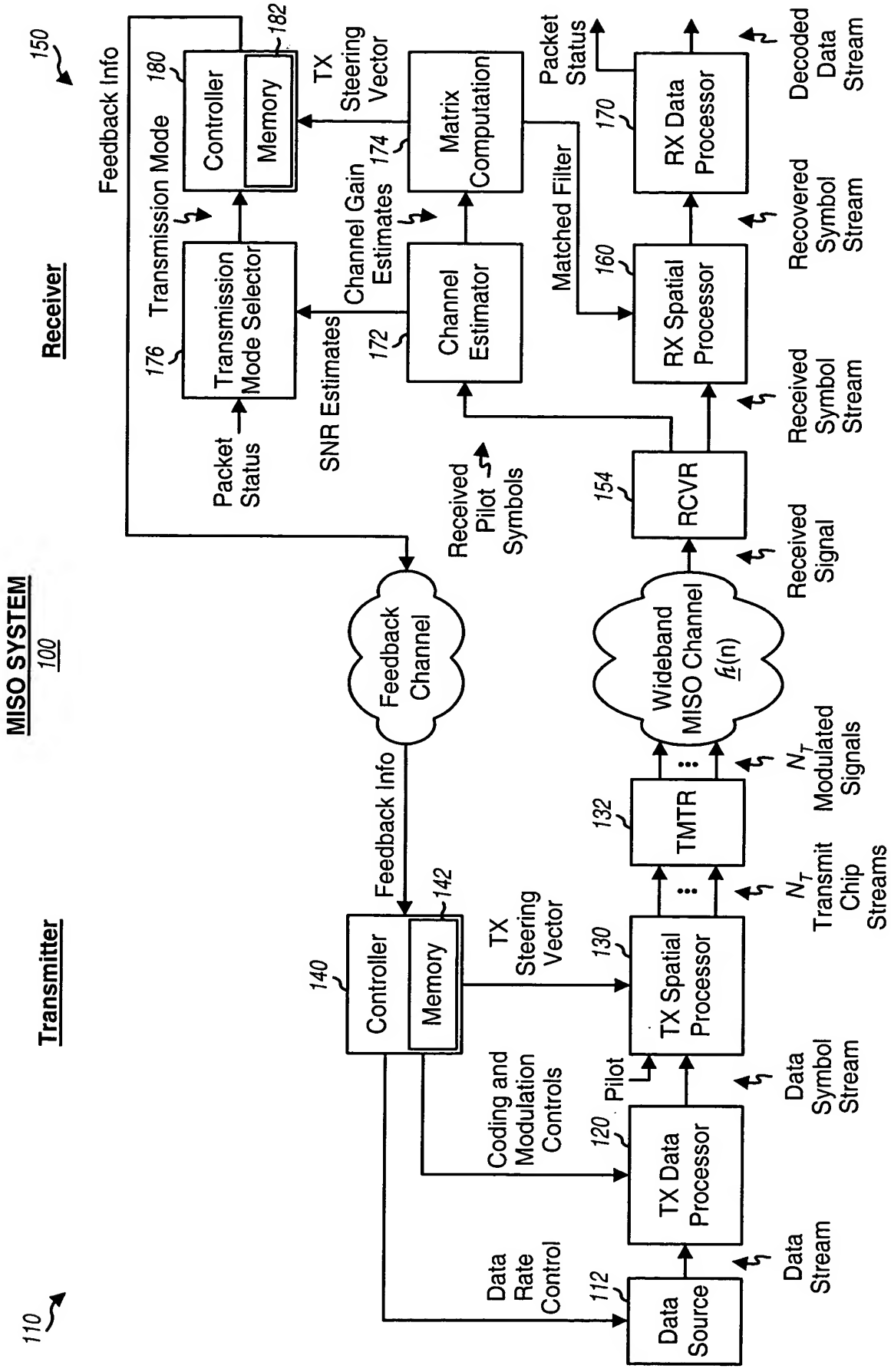
MISO SYSTEM
100
Transmitter
Receiver
110
150
Data Source
112
Data Stream
Data Rate Control
TX Data Processor
120
Coding and Modulation Controls
Pilot
Data Symbol Stream
TX Spatial Processor
130
TX Steering Vector
Controller
140
Memory
142
Feedback Info
Feedback Channel
TMTR
132
N_T Transmit Chip Streams
Wideband MISO Channel $\underline{H}(n)$
N_T Modulated Signals
RCVR
154
Received Signal
Received Pilot Symbols
Packet Status
Transmission Mode Selector
176
Transmission Mode
Feedback Info
Controller
180
Memory
182
TX Steering Vector
Matrix Computation
174
Channel Gain Estimates
SNR Estimates
Channel Estimator
172
Matched Filter
RX Spatial Processor
160
Received Symbol Stream
RX Data Processor
170
Packet Status
Recovered Symbol Stream
Decoded Data Stream

FIG. 1

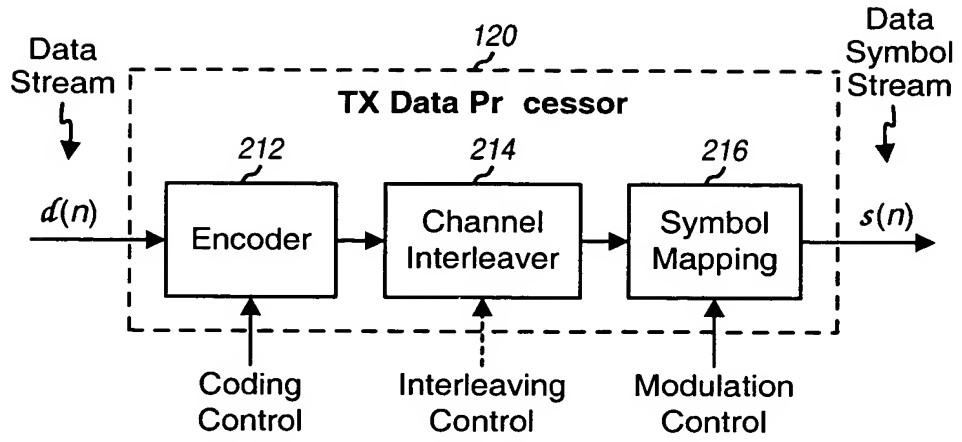
Data Stream
120
TX Data Pr cessor
Data Symbol Stream
212
214
216
d(n)
Encoder
Channel Interleaver
Symbol Mapping
s(n)
Coding Control
Interleaving Control
Modulation Control

FIG. 2

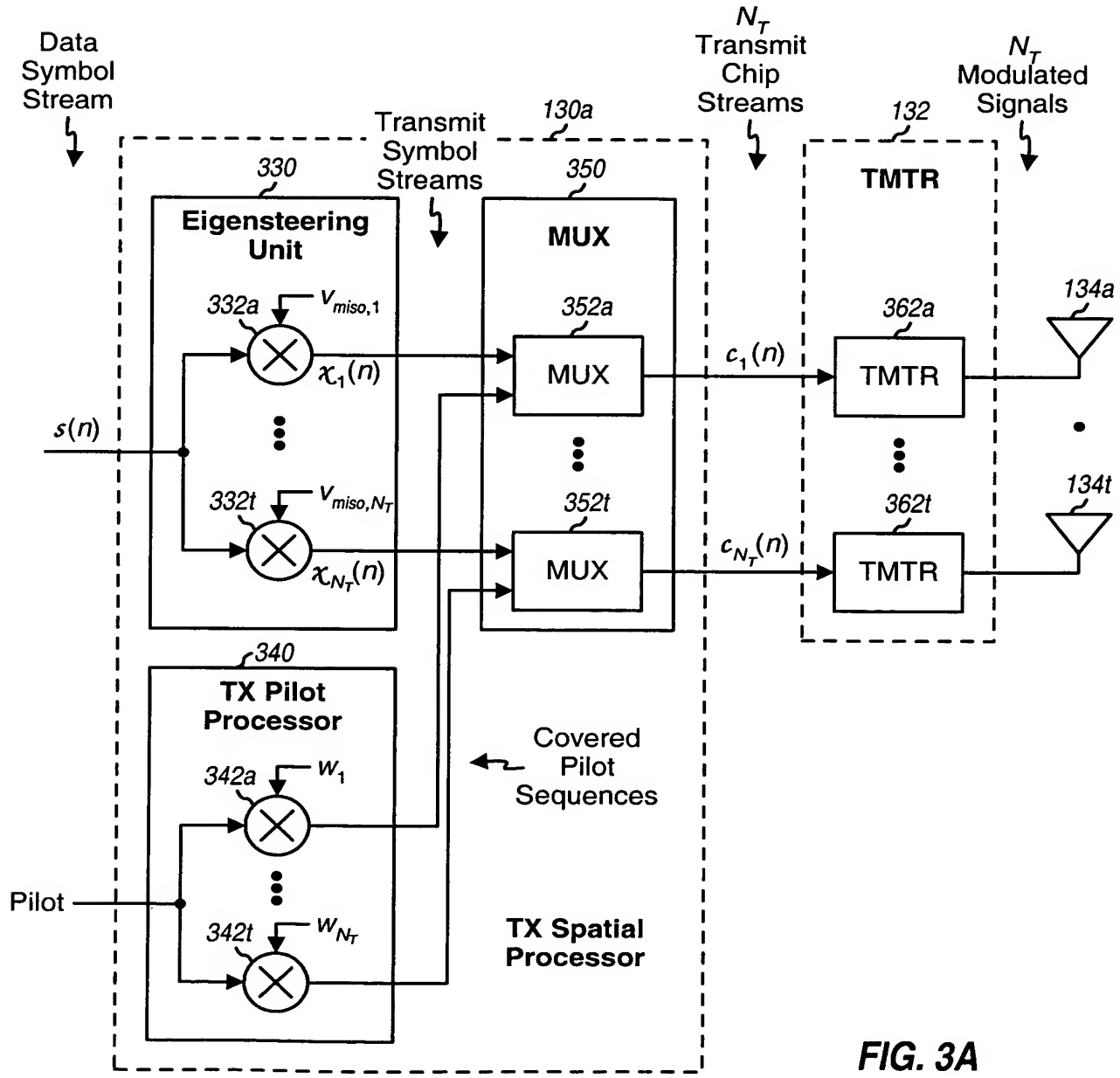
Data Symbol Stream
Transmit Symbol Streams
130a
330
350
N_T Transmit Chip Streams
132
N_T Modulated Signals
Eigensteering Unit
MUX
TMTR
332a
$v_{miso,1}$
352a
362a
134a
$x_1(n)$
$c_1(n)$
s(n)
332t
v_{miso,N_T}
352t
362t
134t
$x_{N_T}(n)$
$c_{N_T}(n)$
340
TX Pilot Processor
Covered Pilot Sequences
342a
w_1
Pilot
342t
w_{N_T}
TX Spatial Processor

FIG. 3A

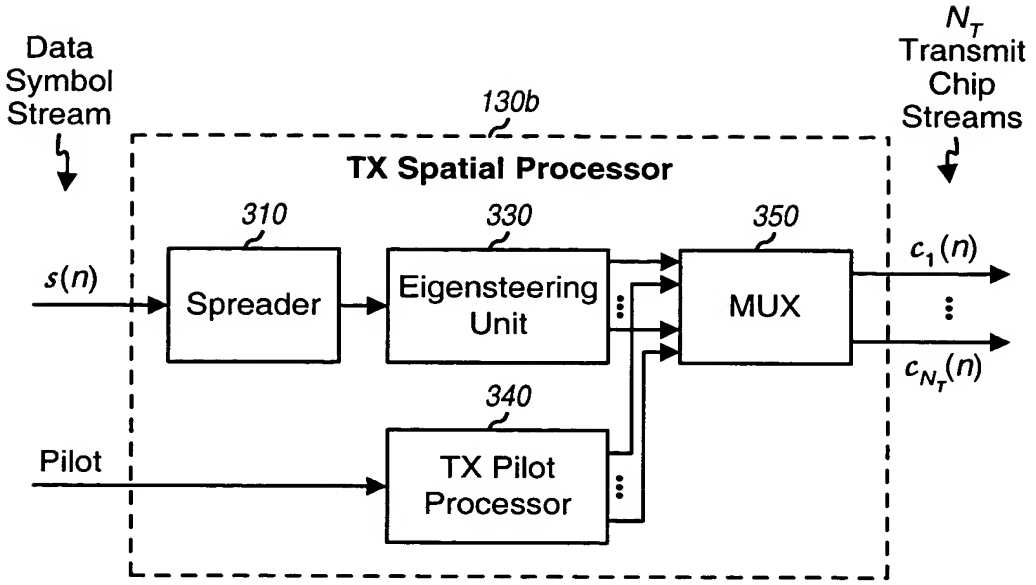
Data Symbol Stream
130b
TX Spatial Processor
N_T Transmit Chip Streams
310
330
350
s(n)
Spreader
Eigensteering Unit
MUX
$c_1(n)$
$c_{N_T}(n)$
340
Pilot
TX Pilot Processor

FIG. 3B

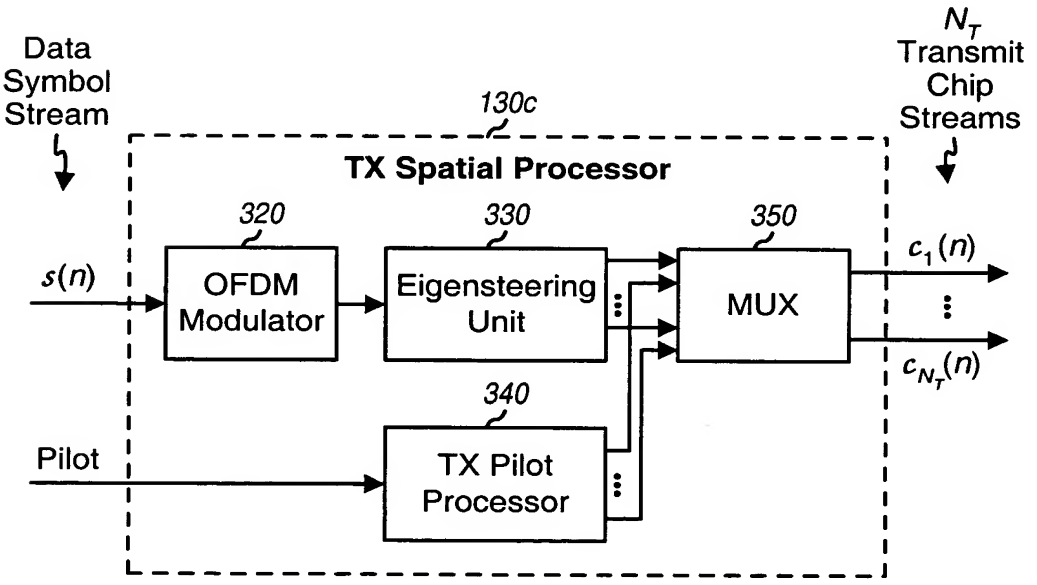
Data Symbol Stream
130c
TX Spatial Processor
N_T Transmit Chip Streams
320
330
350
s(n)
OFDM Modulator
Eigensteering Unit
MUX
$c_1(n)$
$c_{N_T}(n)$
340
Pilot
TX Pilot Processor

FIG. 3C

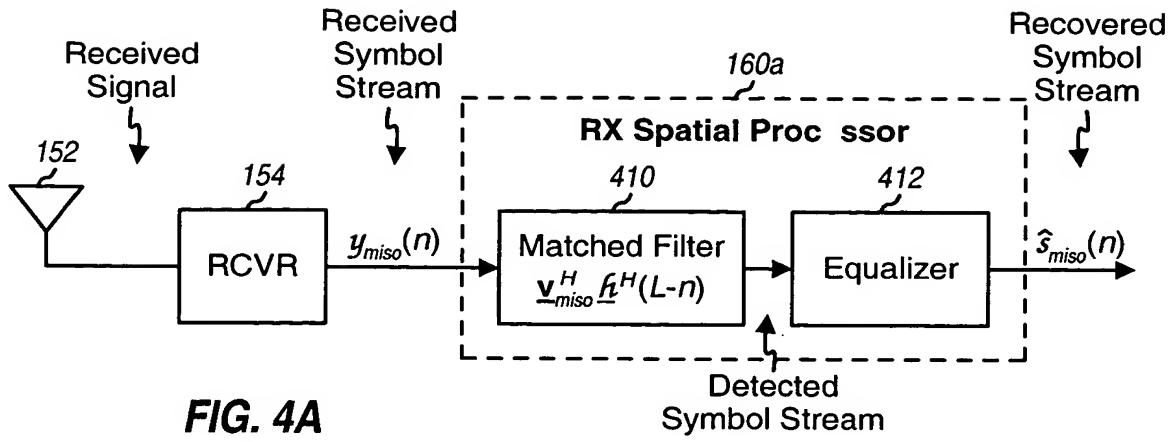

FIG. 4A

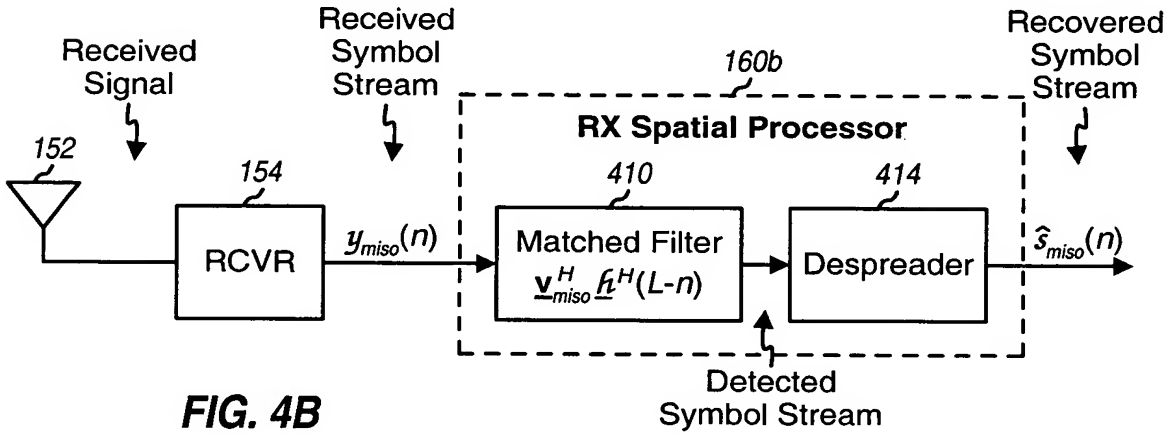

FIG. 4B

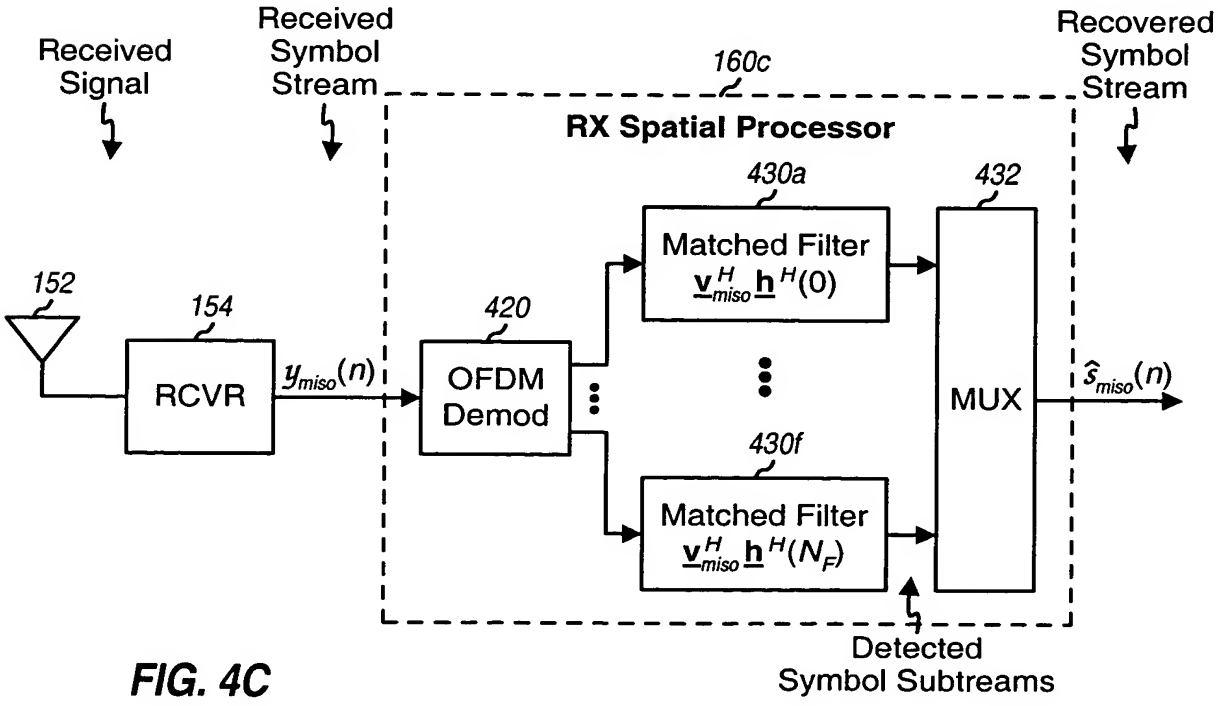

FIG. 4C

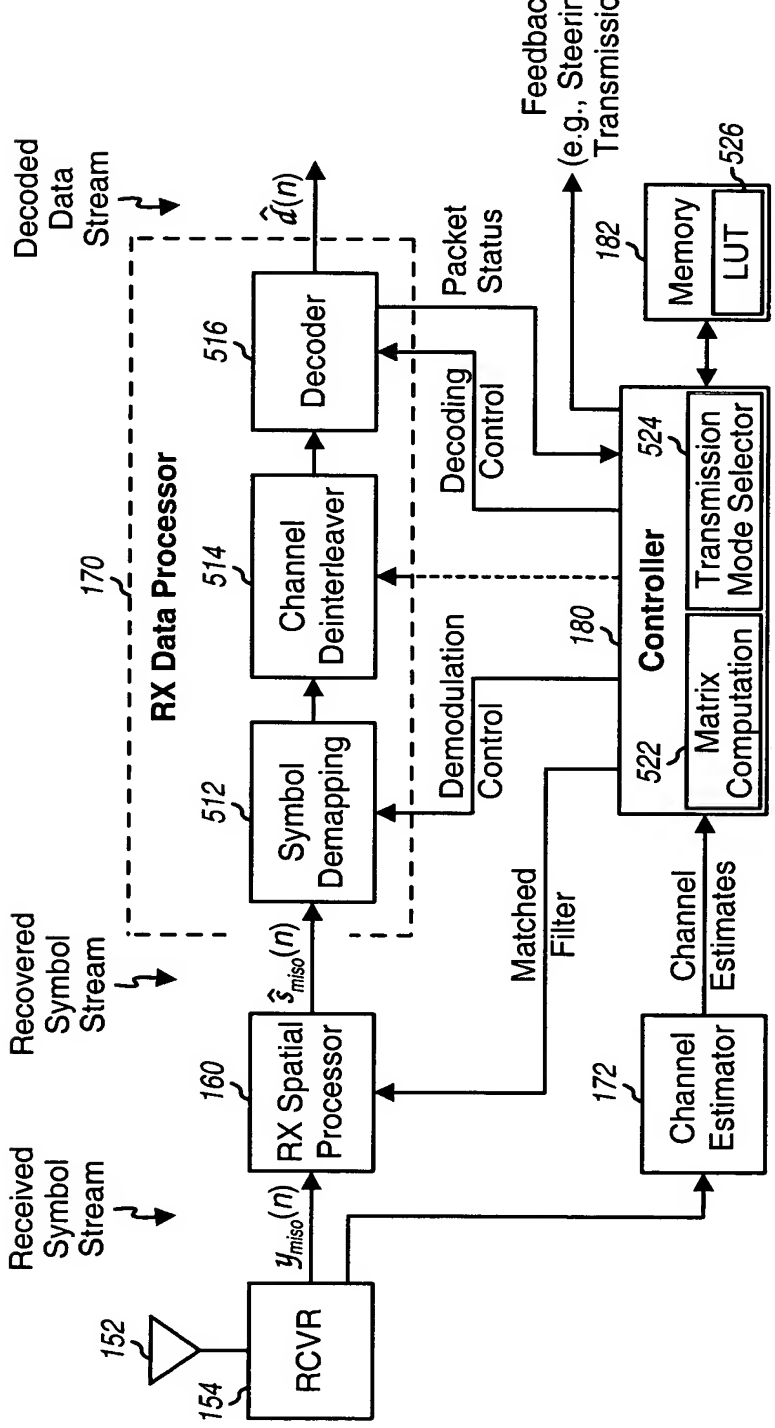
150x
Decoded Data Stream
Feedback Info (e.g., Steering Vector, Transmission Mode)
Packet Status
RX Data Processor
170
Decoder
516
$\hat{d}(n)$
Channel Deinterleaver
514
Decoding Control
Memory
182
LUT
526
Controller
180
524
Transmission Mode Selector
Demodulation Control
Symbol Demapping
512
Matrix Computation
522
Recovered Symbol Stream
$\hat{s}_{miso}(n)$
Matched Filter
RX Spatial Processor
160
Channel Estimates
Channel Estimator
172
Received Symbol Stream
$y_{miso}(n)$
RCVR
154
152

FIG. 5

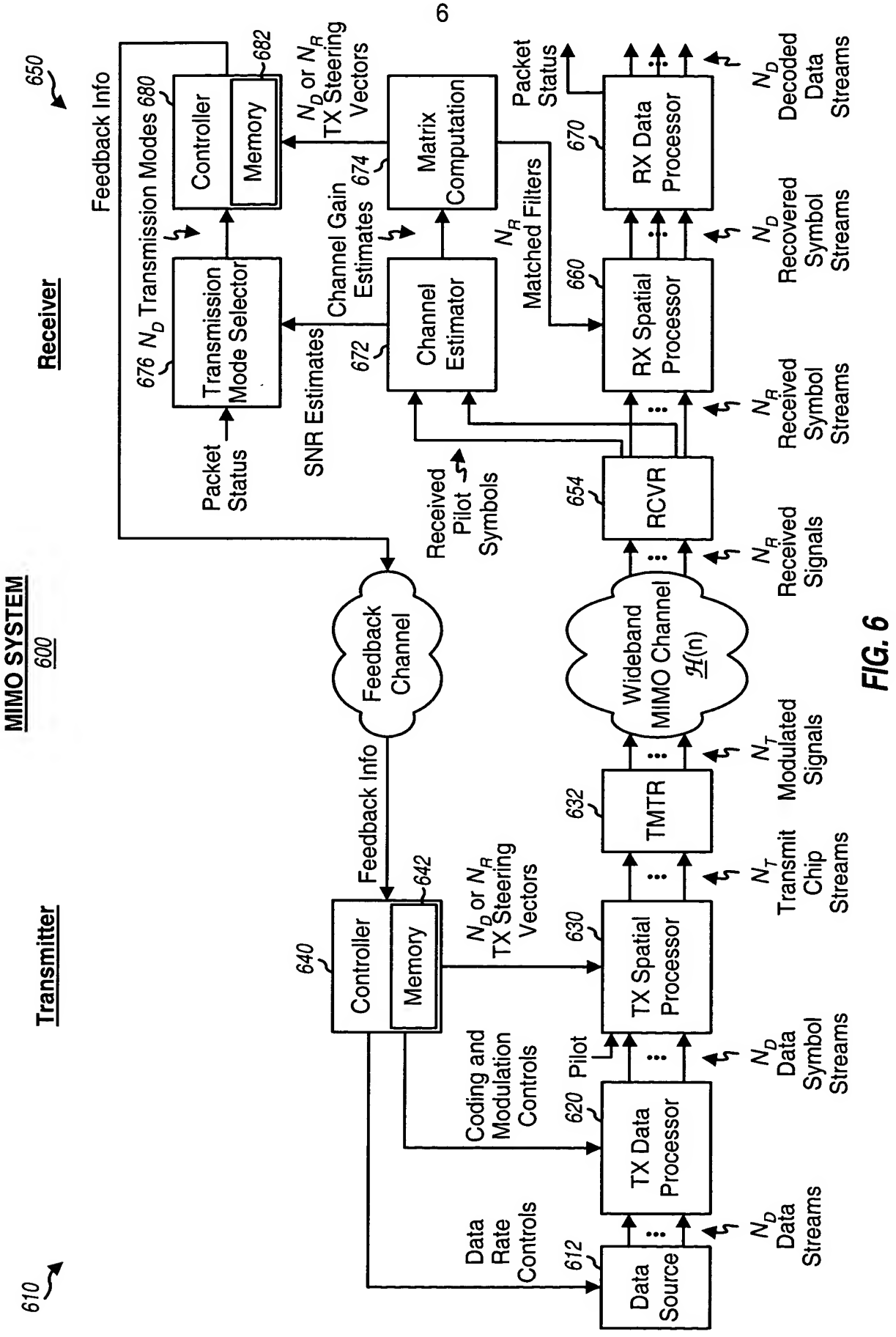
MIMO SYSTEM
600
Transmitter
Receiver
610
650
Data Source
612
Data Streams
N_D
Data Rate Controls
TX Data Processor
620
Coding and Modulation Controls
Pilot
Data Symbol Streams
N_D
TX Spatial Processor
630
N_D or N_R TX Steering Vectors
Controller
640
Memory
642
Feedback Info
Feedback Channel
TMTR
632
Transmit Chip Streams
N_T
Modulated Signals
N_T
Wideband MIMO Channel $\underline{H}(n)$
Received Signals
N_R
RCVR
654
Received Pilot Symbols
Channel Estimator
672
SNR Estimates
Channel Gain Estimates
674
Matrix Computation
N_D or N_R TX Steering Vectors
Controller
680
Memory
682
Feedback Info
Transmission Mode Selector
676
N_D Transmission Modes
Packet Status
Matched Filters
N_R
RX Spatial Processor
660
Received Symbol Streams
N_R
Recovered Symbol Streams
N_D
RX Data Processor
670
Packet Status
Decoded Data Streams
N_D

FIG. 6

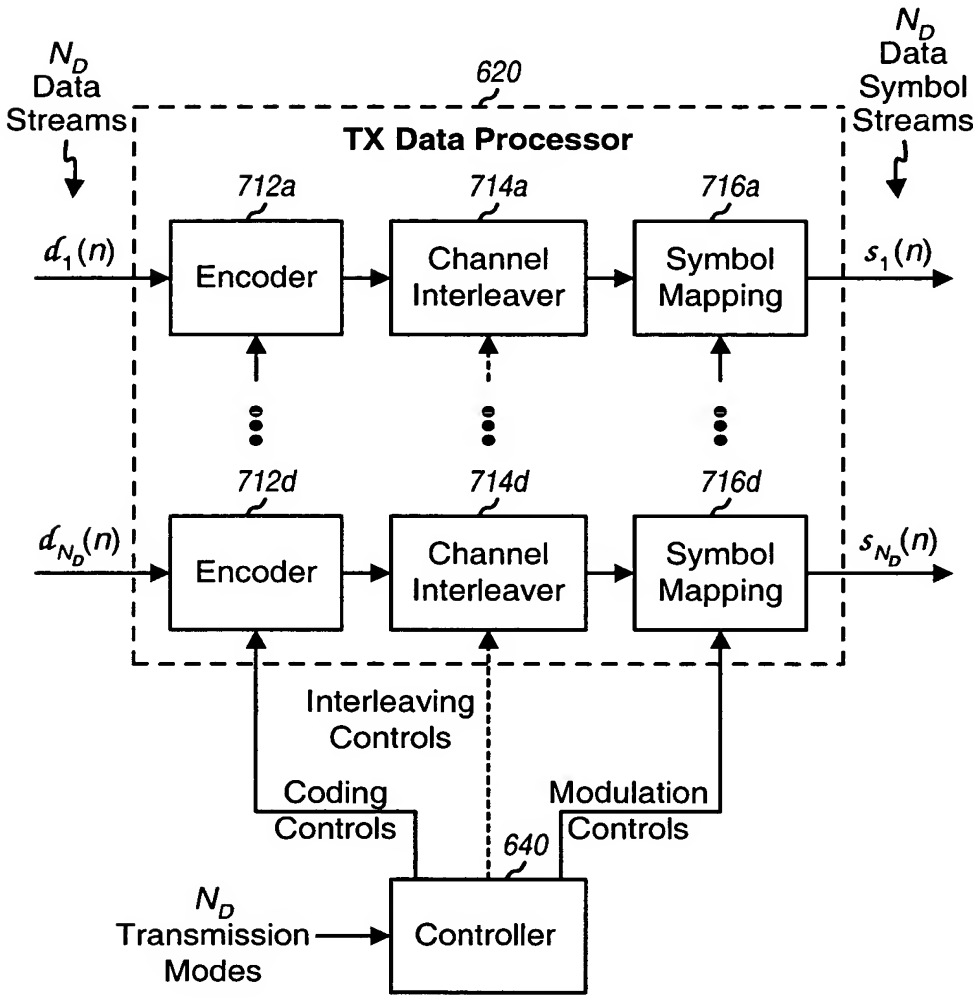
N_D Data Streams
620
TX Data Processor
N_D Data Symbol Streams
712a
714a
716a
$d_1(n)$
Encoder
Channel Interleaver
Symbol Mapping
$s_1(n)$
712d
714d
716d
$d_{N_D}(n)$
Encoder
Channel Interleaver
Symbol Mapping
$s_{N_D}(n)$
Interleaving Controls
Coding Controls
Modulation Controls
640
N_D Transmission Modes
Controller

FIG. 7

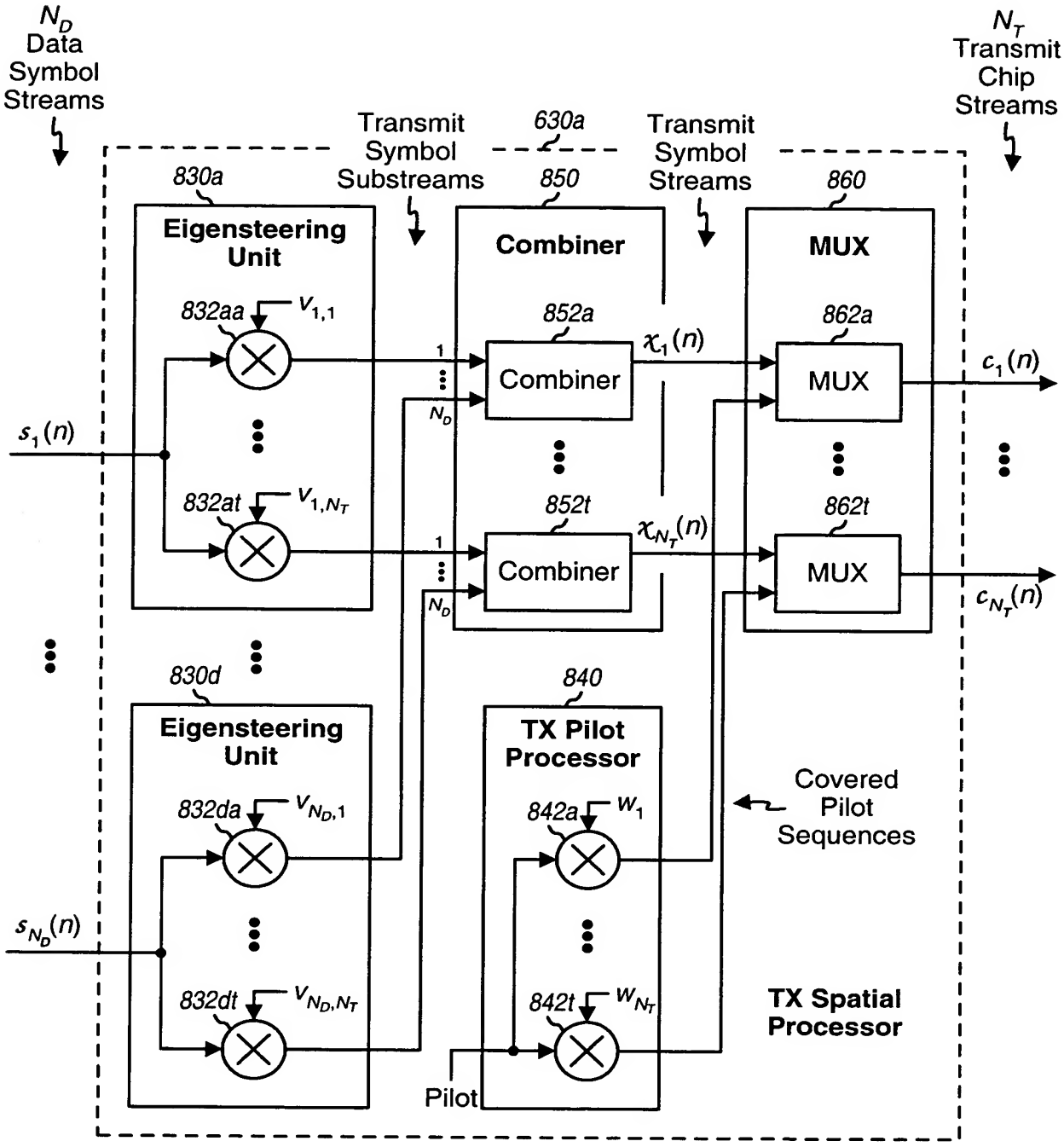
N_D Data Symbol Streams
N_T Transmit Chip Streams
Transmit Symbol Substreams
630a
Transmit Symbol Streams
830a
Eigensteering Unit
850
Combiner
860
MUX
832aa
$V_{1,1}$
852a
Combiner
$x_1(n)$
862a
MUX
$c_1(n)$
$s_1(n)$
832at
V_{1,N_T}
852t
Combiner
$x_{N_T}(n)$
862t
MUX
$c_{N_T}(n)$
830d
Eigensteering Unit
840
TX Pilot Processor
832da
$V_{N_D,1}$
842a
w_1
Covered Pilot Sequences
$s_{N_D}(n)$
832dt
V_{N_D,N_T}
842t
w_{N_T}
TX Spatial Processor
Pilot

FIG. 8A

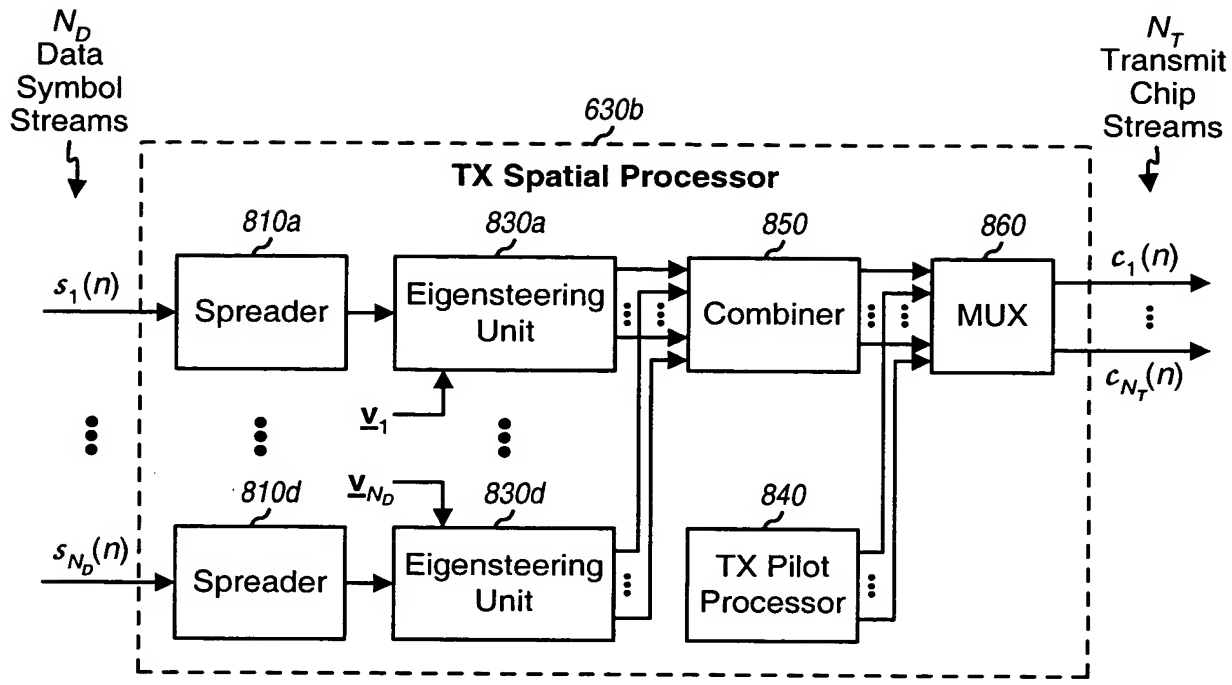
N_D Data Symbol Streams
630b
TX Spatial Processor
N_T Transmit Chip Streams
810a
830a
850
860
$s_1(n)$
Spreader
Eigensteering Unit
Combiner
MUX
$c_1(n)$
$c_{N_T}(n)$
$\underline{v}_1$
$\underline{v}_{N_D}$
810d
830d
840
$s_{N_D}(n)$
Spreader
Eigensteering Unit
TX Pilot Processor

FIG. 8B

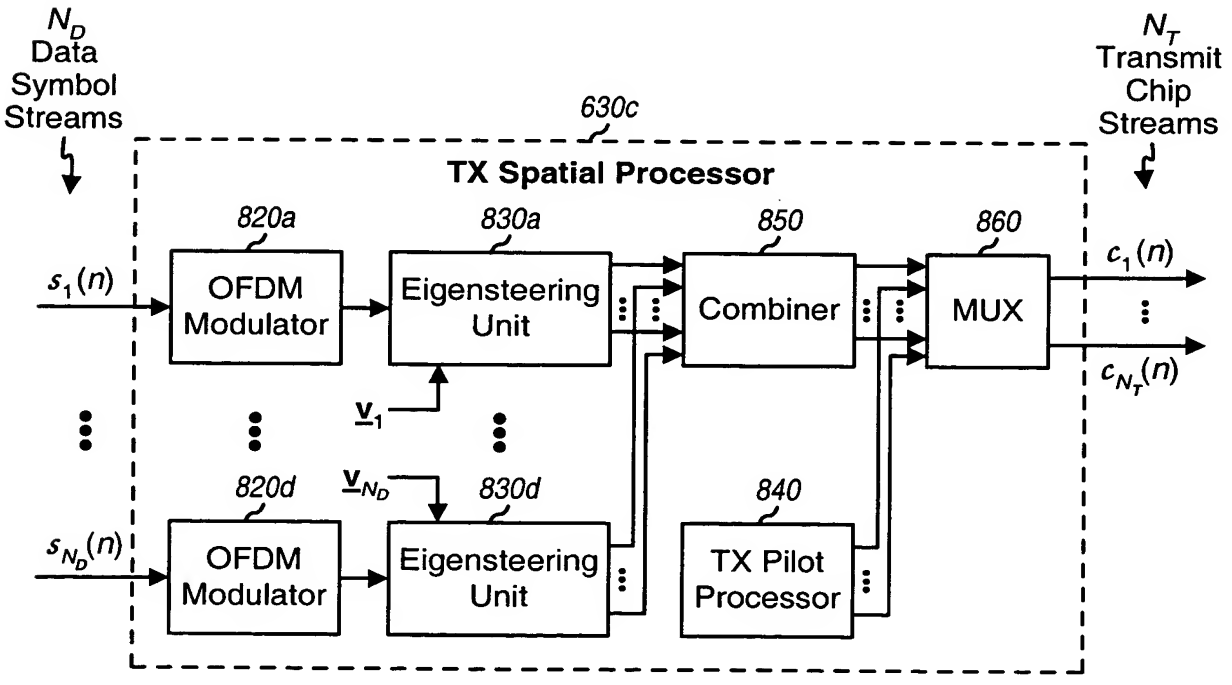
N_D Data Symbol Streams
630c
TX Spatial Processor
N_T Transmit Chip Streams
820a
830a
850
860
$s_1(n)$
OFDM Modulator
Eigensteering Unit
Combiner
MUX
$c_1(n)$
$c_{N_T}(n)$
$\underline{v}_1$
$\underline{v}_{N_D}$
820d
830d
840
$s_{N_D}(n)$
OFDM Modulator
Eigensteering Unit
TX Pilot Processor

FIG. 8C

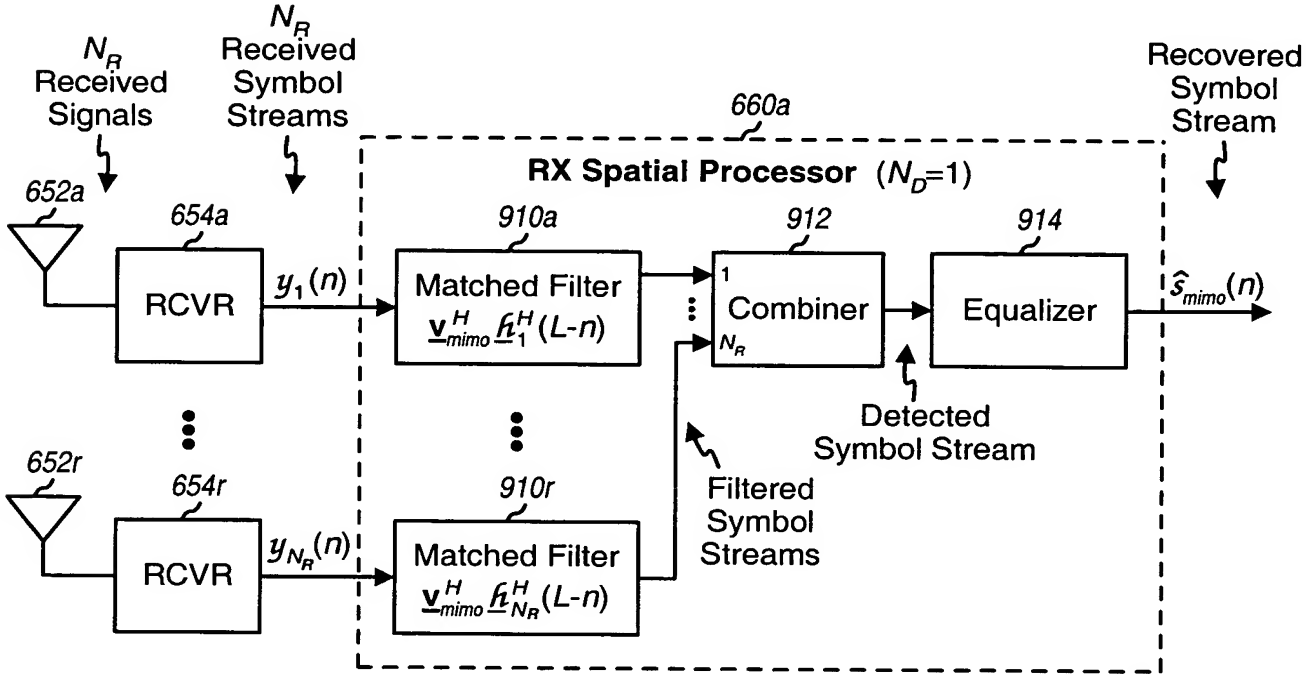
N_R Received Signals
N_R Received Symbol Streams
Recovered Symbol Stream
660a
RX Spatial Processor (N_D=1)
652a
654a
910a
912
914
RCVR
$y_1(n)$
Matched Filter
$\underline{v}_{mimo}^H \underline{h}_1^H(L-n)$
1
Combiner
N_R
Equalizer
$\hat{s}_{mimo}(n)$
Detected Symbol Stream
Filtered Symbol Streams
652r
654r
910r
RCVR
$y_{N_R}(n)$
Matched Filter
$\underline{v}_{mimo}^H \underline{h}_{N_R}^H(L-n)$

FIG. 9A

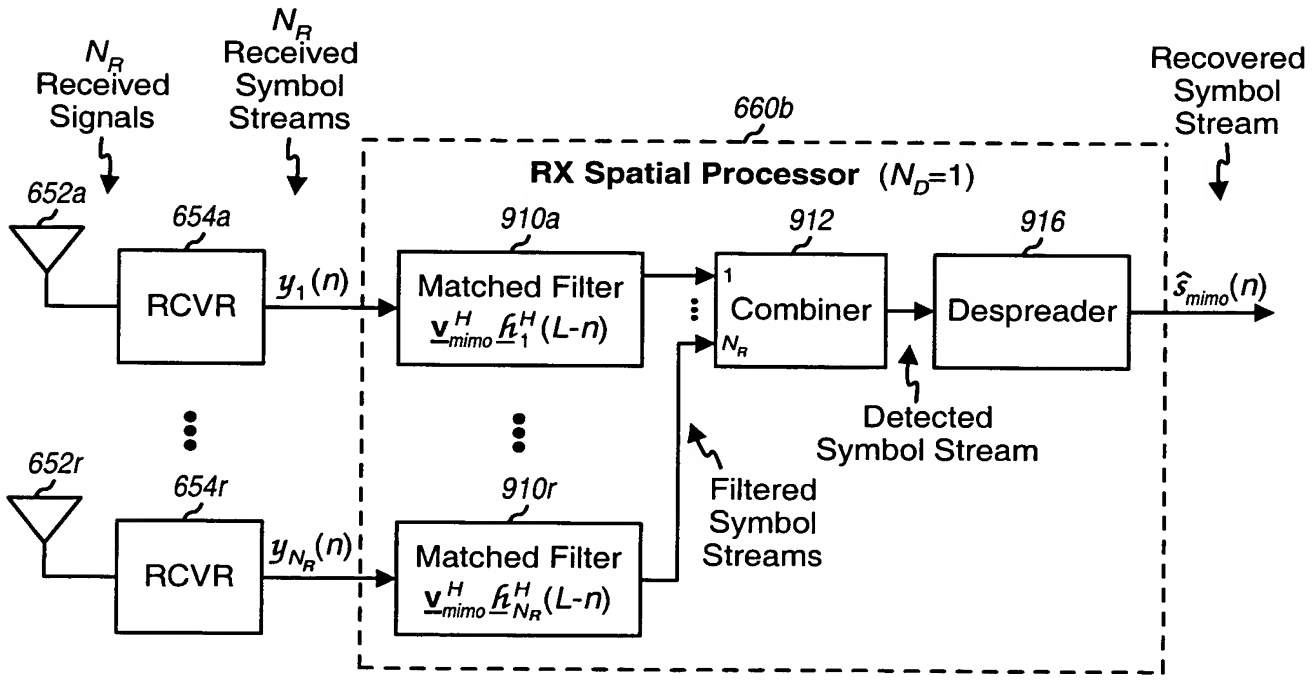
N_R Received Signals
N_R Received Symbol Streams
Recovered Symbol Stream
660b
RX Spatial Processor (N_D=1)
652a
654a
910a
912
916
RCVR
$y_1(n)$
Matched Filter
$\underline{v}_{mimo}^H \underline{h}_1^H(L-n)$
1
Combiner
N_R
Despreader
$\hat{s}_{mimo}(n)$
Detected Symbol Stream
Filtered Symbol Streams
652r
654r
910r
RCVR
$y_{N_R}(n)$
Matched Filter
$\underline{v}_{mimo}^H \underline{h}_{N_R}^H(L-n)$

FIG. 9B

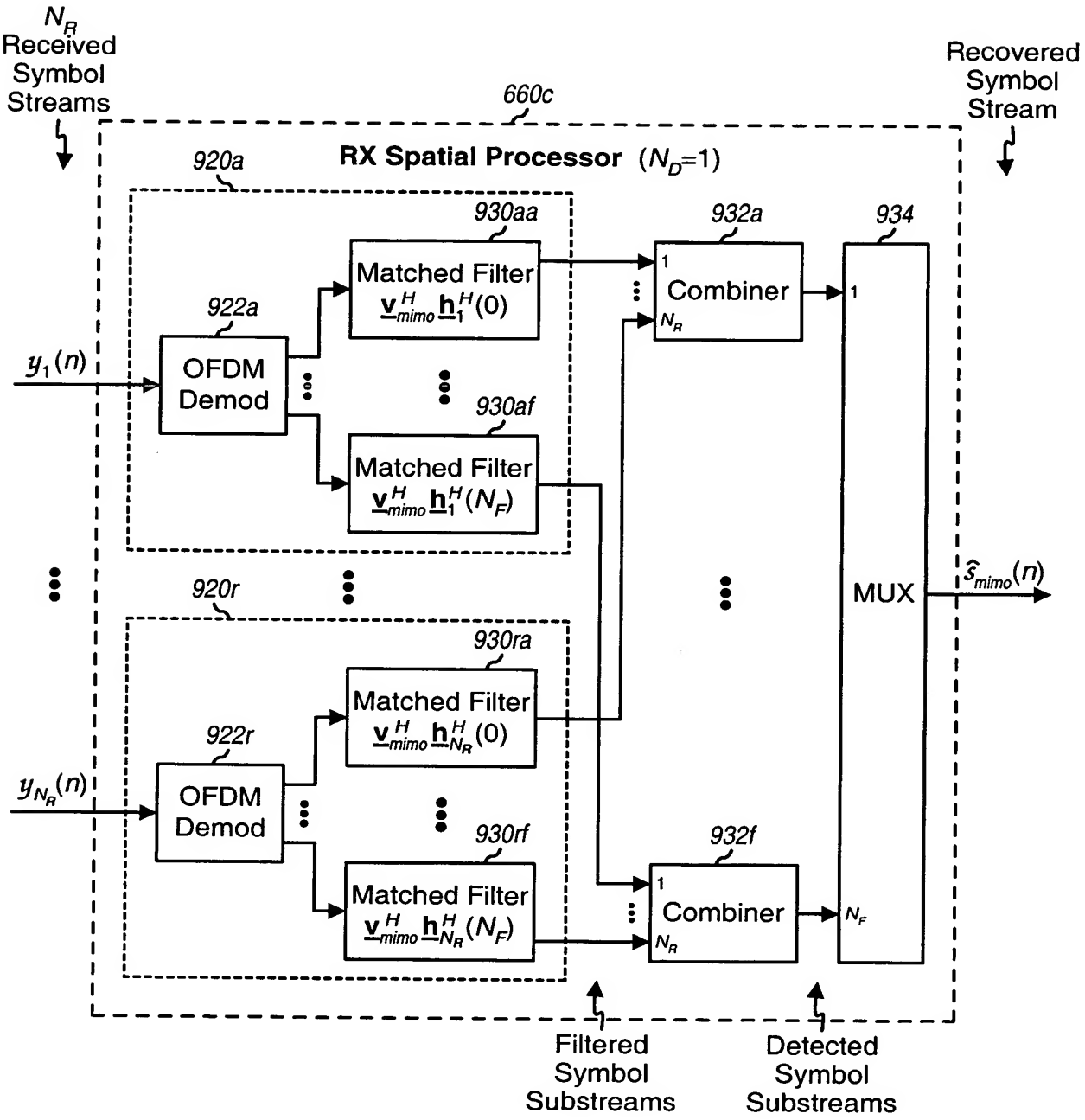
N_R Received Symbol Streams
660c
Recovered Symbol Stream
920a
RX Spatial Processor (N_D=1)
930aa
932a
934
922a
Matched Filter $\underline{v}_{mimo}^H \underline{h}_1^H(0)$
Combiner
$y_1(n)$
OFDM Demod
930af
Matched Filter $\underline{v}_{mimo}^H \underline{h}_1^H(N_F)$
MUX
$\hat{s}_{mimo}(n)$
920r
930ra
922r
Matched Filter $\underline{v}_{mimo}^H \underline{h}_{N_R}^H(0)$
$y_{N_R}(n)$
OFDM Demod
930rf
932f
Matched Filter $\underline{v}_{mimo}^H \underline{h}_{N_R}^H(N_F)$
Combiner
Filtered Symbol Substreams
Detected Symbol Substreams

FIG. 9C

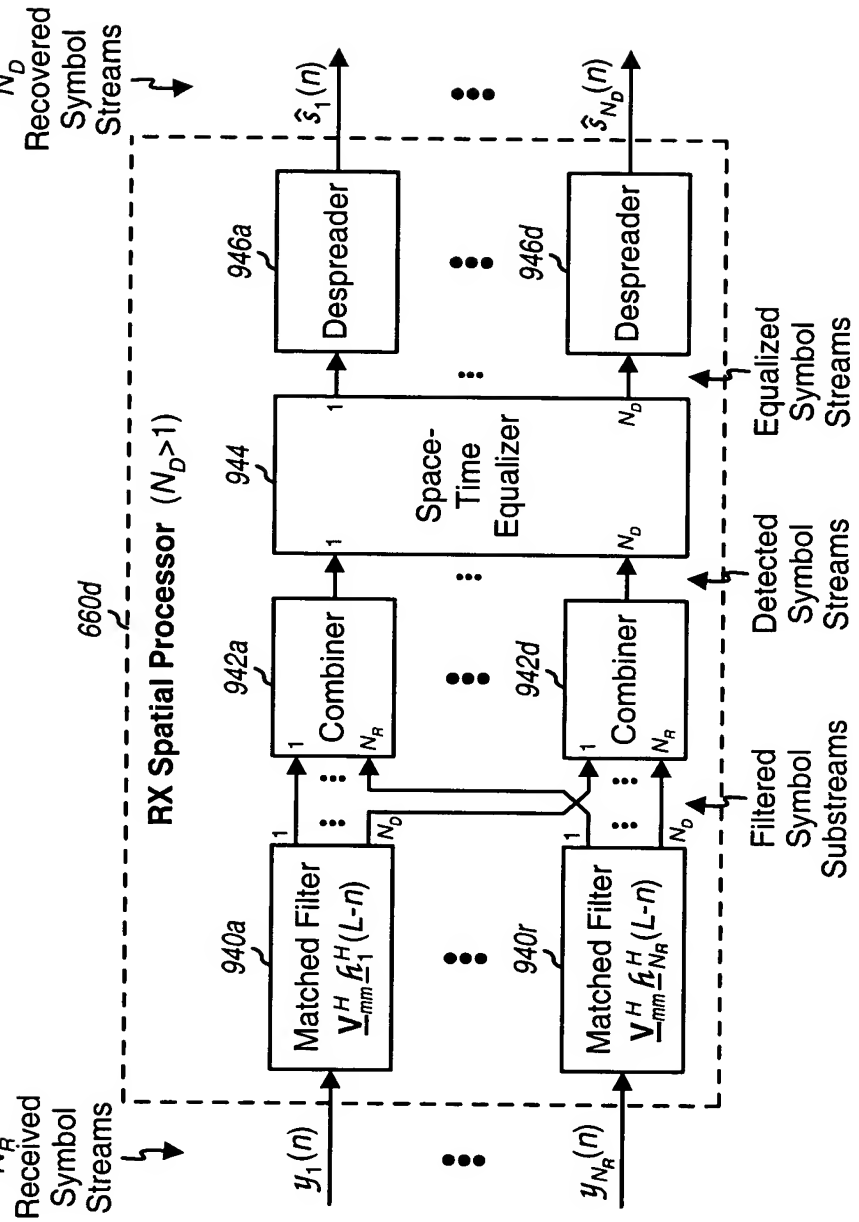
N_R Received Symbol Streams
N_D Recovered Symbol Streams
RX Spatial Processor (N_D>1)
660d
$y_1(n)$
$y_{N_R}(n)$
940a
940r
Matched Filter $\underline{\mathbf{V}}_{mm}^H \underline{\mathbf{f}}_1^H(L-n)$
Matched Filter $\underline{\mathbf{V}}_{mm}^H \underline{\mathbf{f}}_{N_R}^H(L-n)$
Filtered Symbol Substreams
942a
942d
Combiner
Detected Symbol Streams
944
Space-Time Equalizer
Equalized Symbol Streams
946a
946d
Despreader
$\hat{s}_1(n)$
$\hat{s}_{N_D}(n)$

FIG. 9D

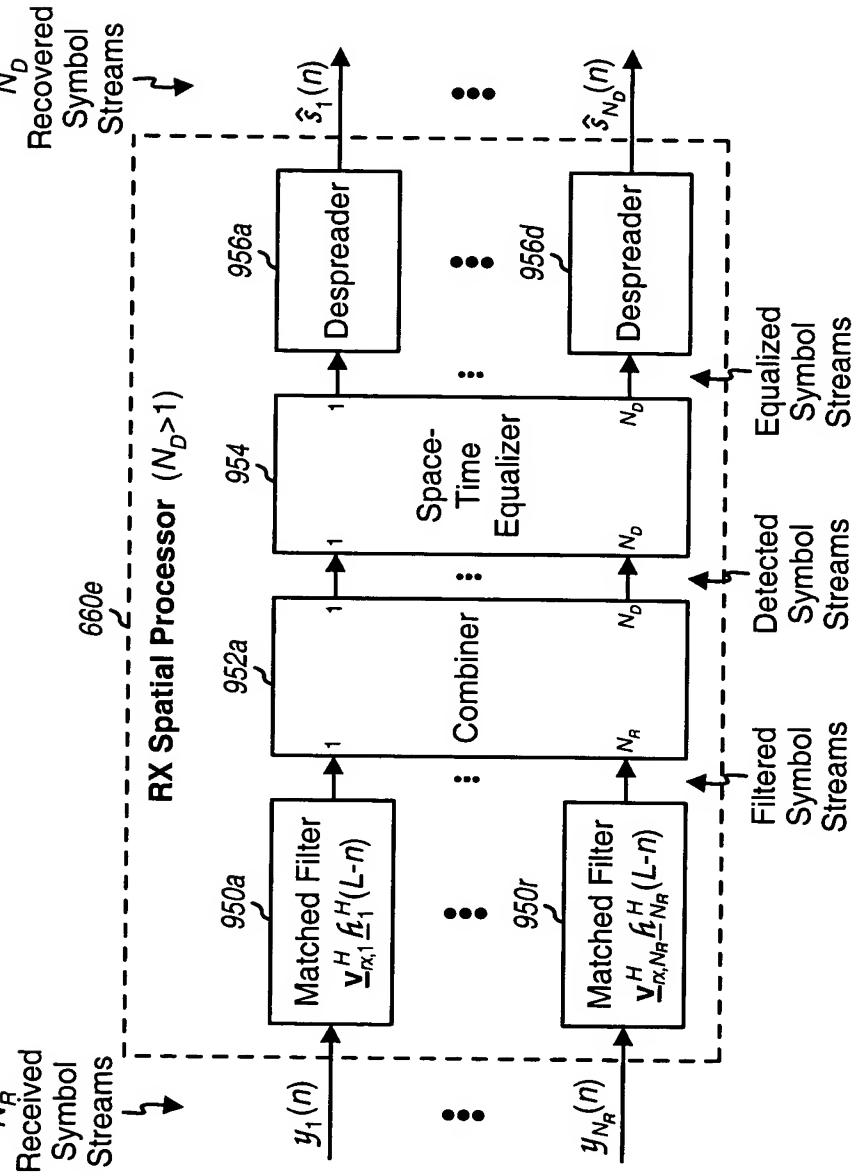
N_R Received Symbol Streams
N_D Recovered Symbol Streams
RX Spatial Processor (N_D>1)
660e
950a
Matched Filter
$\underline{\mathbf{v}}^H_{rx,1}\underline{h}^H_1(L-n)$
950r
Matched Filter
$\underline{\mathbf{v}}^H_{rx,N_R}\underline{h}^H_{N_R}(L-n)$
952a
Combiner
954
Space-Time Equalizer
956a
Despreader
956d
Despreader
$y_1(n)$
$y_{N_R}(n)$
$\hat{s}_1(n)$
$\hat{s}_{N_D}(n)$
Filtered Symbol Streams
Detected Symbol Streams
Equalized Symbol Streams

FIG. 9E

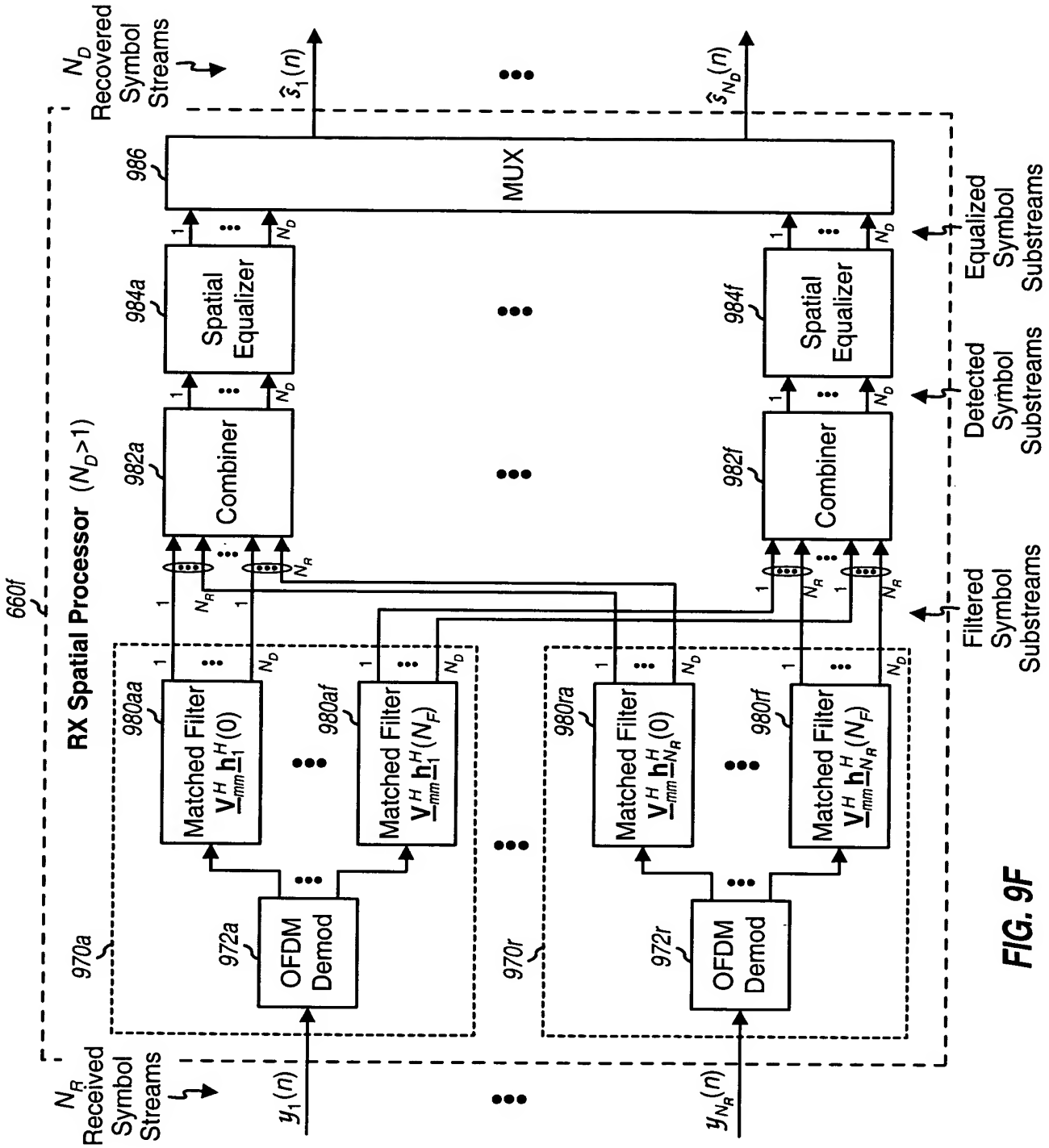
660f
RX Spatial Processor (N_D>1)
N_R Received Symbol Streams
N_D Recovered Symbol Streams
970a
970r
972a
OFDM Demod
972r
980aa
Matched Filter $\underline{\mathbf{v}}_{mm}^H \underline{\mathbf{h}}_1^H(0)$
980af
Matched Filter $\underline{\mathbf{v}}_{mm}^H \underline{\mathbf{h}}_1^H(N_F)$
980ra
Matched Filter $\underline{\mathbf{v}}_{mm}^H \underline{\mathbf{h}}_{N_R}^H(0)$
980rf
Matched Filter $\underline{\mathbf{v}}_{mm}^H \underline{\mathbf{h}}_{N_R}^H(N_F)$
982a
Combiner
982f
Combiner
984a
Spatial Equalizer
984f
Spatial Equalizer
986
MUX
$y_1(n)$
$y_{N_R}(n)$
$\hat{s}_1(n)$
$\hat{s}_{N_D}(n)$
Filtered Symbol Substreams
Detected Symbol Substreams
Equalized Symbol Substreams

FIG. 9F

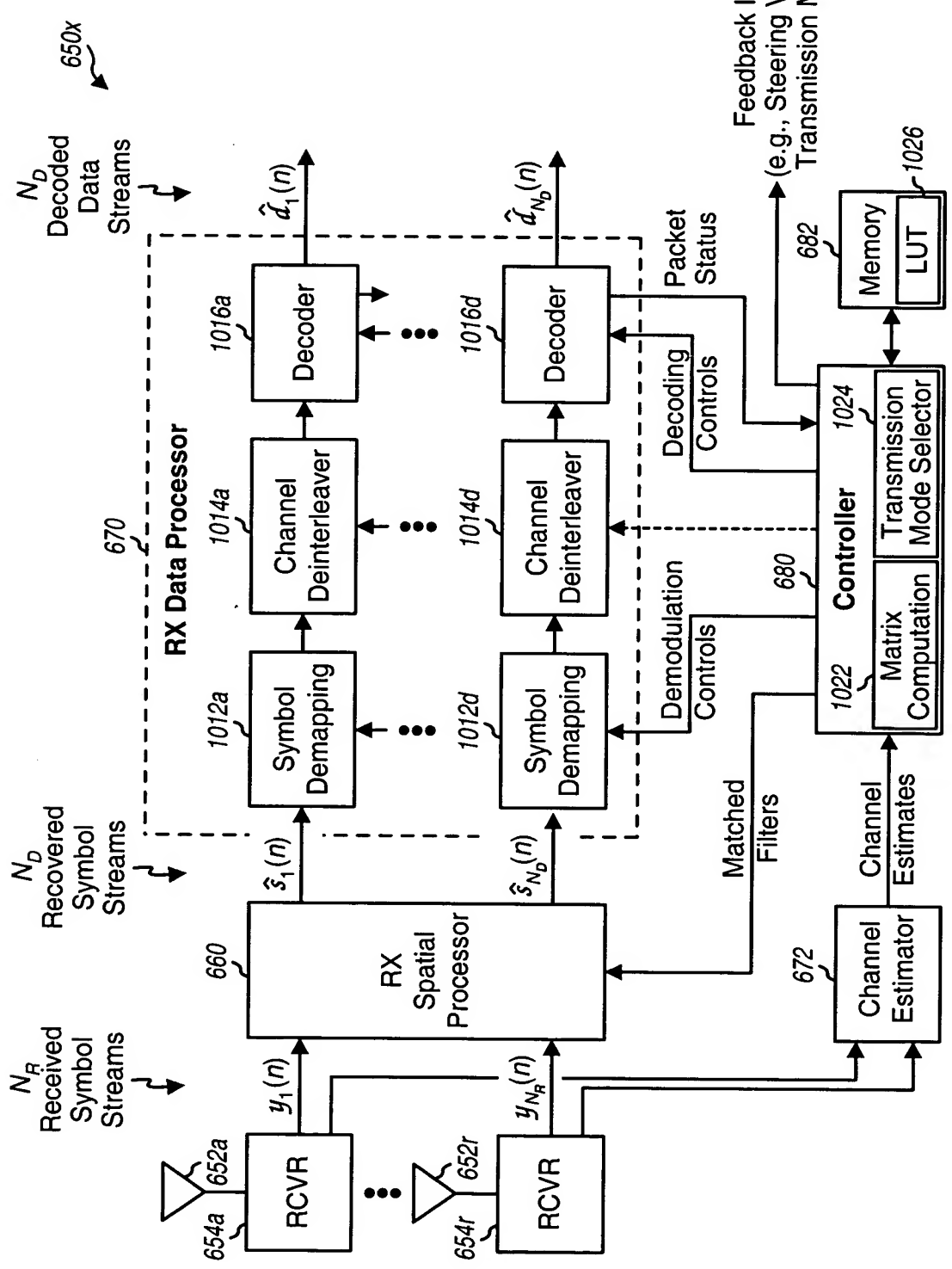
650x
N_D Decoded Data Streams
N_D Recovered Symbol Streams
N_R Received Symbol Streams
RX Data Processor
670
RX Spatial Processor
660
Symbol Demapping
1012a
1012d
Channel Deinterleaver
1014a
1014d
Decoder
1016a
1016d
$\hat{s}_1(n)$
$\hat{s}_{N_D}(n)$
$\hat{d}_1(n)$
$\hat{d}_{N_D}(n)$
$y_1(n)$
$y_{N_R}(n)$
RCVR
652a
652r
654a
654r
Matched Filters
Channel Estimates
Channel Estimator
672
Demodulation Controls
Decoding Controls
Packet Status
Feedback Info (e.g., Steering Vectors, Transmission Modes)
Controller
680
Matrix Computation
1022
Transmission Mode Selector
1024
Memory
682
LUT
1026

FIG. 10

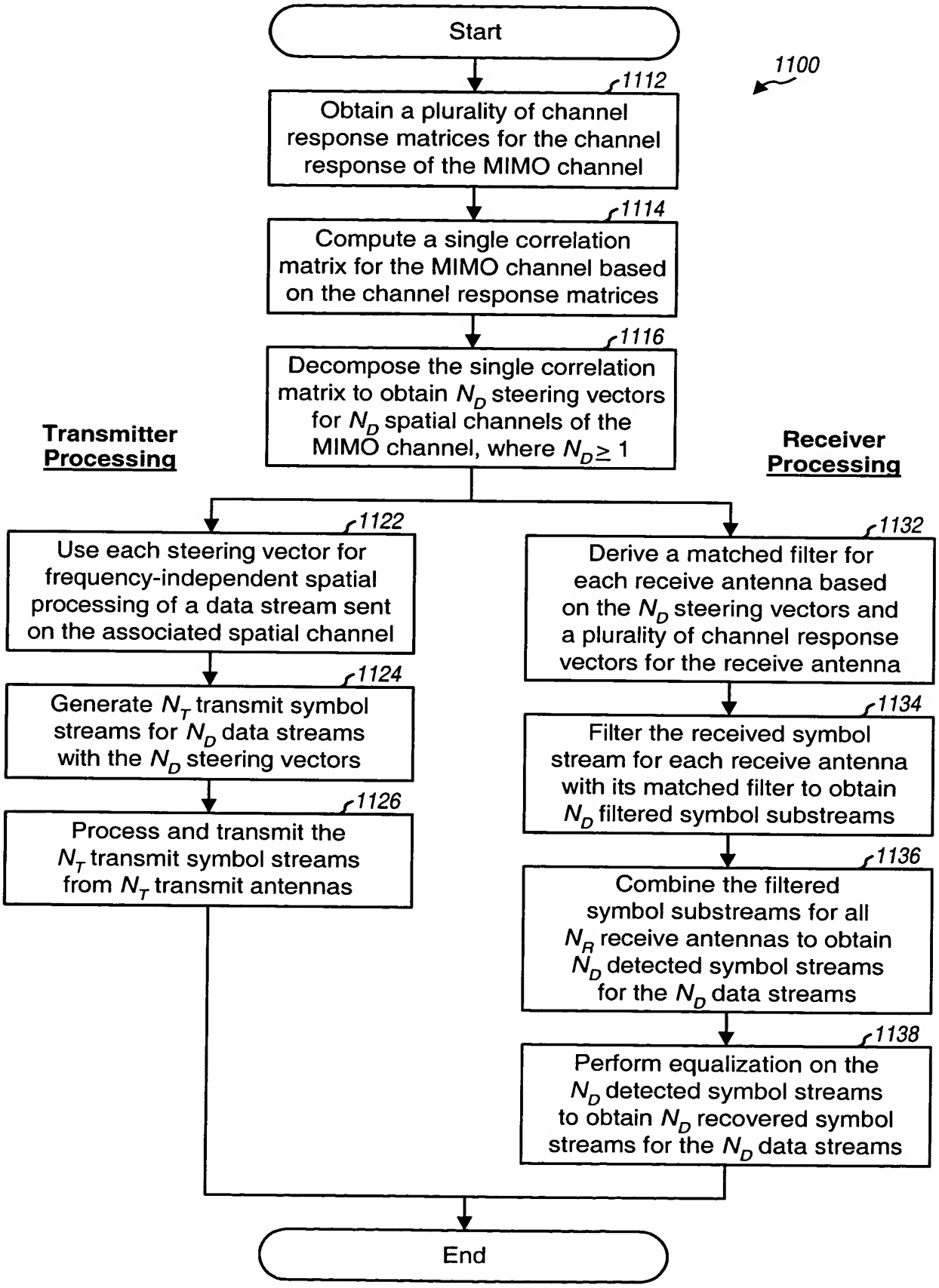
Start
1100
1112
Obtain a plurality of channel response matrices for the channel response of the MIMO channel
1114
Compute a single correlation matrix for the MIMO channel based on the channel response matrices
1116
Decompose the single correlation matrix to obtain N_D steering vectors for N_D spatial channels of the MIMO channel, where $N_D \geq 1$
Transmitter Processing
Receiver Processing
1122
Use each steering vector for frequency-independent spatial processing of a data stream sent on the associated spatial channel
1124
Generate N_T transmit symbol streams for N_D data streams with the N_D steering vectors
1126
Process and transmit the N_T transmit symbol streams from N_T transmit antennas
1132
Derive a matched filter for each receive antenna based on the N_D steering vectors and a plurality of channel response vectors for the receive antenna
1134
Filter the received symbol stream for each receive antenna with its matched filter to obtain N_D filtered symbol substreams
1136
Combine the filtered symbol substreams for all N_R receive antennas to obtain N_D detected symbol streams for the N_D data streams
1138
Perform equalization on the N_D detected symbol streams to obtain N_D recovered symbol streams for the N_D data streams
End

FIG. 11

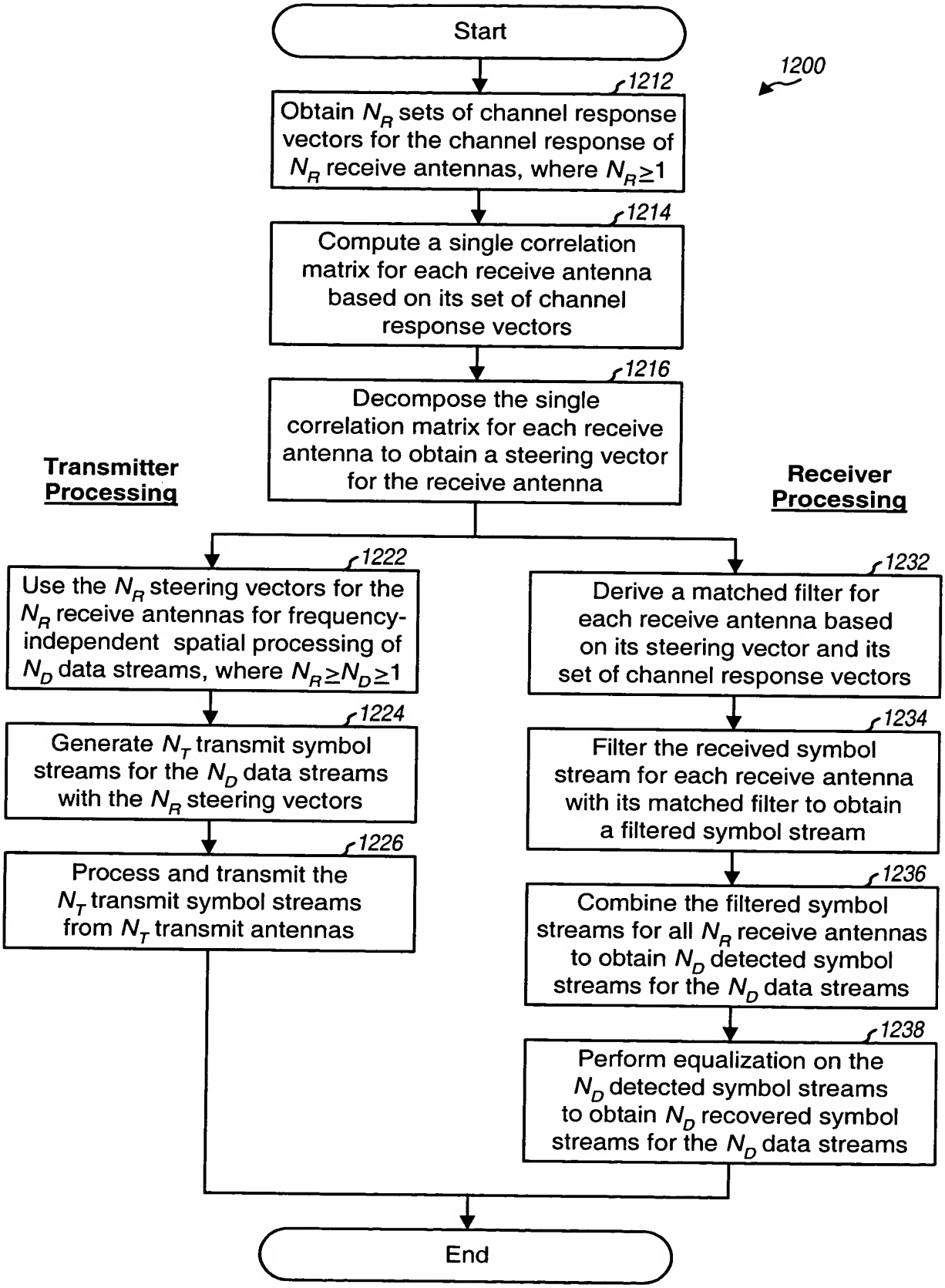
Start
1200
1212
Obtain N_R sets of channel response vectors for the channel response of N_R receive antennas, where $N_R \geq 1$
1214
Compute a single correlation matrix for each receive antenna based on its set of channel response vectors
1216
Decompose the single correlation matrix for each receive antenna to obtain a steering vector for the receive antenna
Transmitter Processing
Receiver Processing
1222
Use the N_R steering vectors for the N_R receive antennas for frequency-independent spatial processing of N_D data streams, where $N_R \geq N_D \geq 1$
1224
Generate N_T transmit symbol streams for the N_D data streams with the N_R steering vectors
1226
Process and transmit the N_T transmit symbol streams from N_T transmit antennas
1232
Derive a matched filter for each receive antenna based on its steering vector and its set of channel response vectors
1234
Filter the received symbol stream for each receive antenna with its matched filter to obtain a filtered symbol stream
1236
Combine the filtered symbol streams for all N_R receive antennas to obtain N_D detected symbol streams for the N_D data streams
1238
Perform equalization on the N_D detected symbol streams to obtain N_D recovered symbol streams for the N_D data streams
End

FIG. 12